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The Changes in Weight of Hosiery Fabrics in the Finishing Processes.

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NOTE.—These results, though directly applicable to Hosiery, are of interest also to Cloth and Flannel Manufacturers.

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CONTENTS.

Part I.

THE DETERMINATION OF THE CHANGES IN WEIGHT AND THEIR LOCATION.

Part II.

THE EFFECT OF FINISHING PROCESSES ON THE REGAIN OF HOSIERY MATERIAL.

"REGAIN" DEFINITIONS AT END OF PART II.

Part I.

The Determination of

The Changes in Weight

and their Location.

Short Abstract.

The paper contains an account of both large-scale and small-scale experiments in which the losses in the finishing processes of cotton, botany wool, and crossbred wool are determined.

These losses are determined on the basis of bone-dry weight and of the weight after conditioning in an atmosphere of standard humidity. The losses reckoned on the basis of the dry weight are shown to be less than the losses observed in the factory, but the losses reckoned on the basis of conditioned weight are of the same order of magnitude as those observed in the factory. The losses are, therefore, mainly due to the impairing of the hygroscopic capacity of the material produced by the finishing. This is shown to be due to the final operation of hot pressing.

The variations shown when the same kind of material goes through processes nominally the same, demonstrate the difficulty of accurate control of processes and reproduction of results in hosiery finishing.

Introduction.

The attention of the Association was first drawn to this subject by one of the large hosiery manufacturers. The only data available were the records of the weights of the material sent to the finisher, and of the weights returned. Obviously such figures afforded no reliable means of estimating the losses since each weight depended upon the regain of the material, which in turn depended in a complicated manner on the atmospheric conditions prevailing during the twenty-four hours or so previous to weighing.

It was felt, however, by this firm that the differences between the weights before and after finishing were greater than they should have been, and it was suggested that we should investigate the subject. The authors visited one of the hosiery factories, and the outcome of the discussions was the formulation of a programme of experiments designed to determine the losses, and find if possible which of the processes was mainly responsible for them.

LARGE SCALE EXPERIMENTS.

Method of Experiment.

It was decided at the outset that it was preferable to work on rolls of fabric of the ordinary weight rather than upon small pieces. There is always a tendency for samples of unusual weight to get treatment which cannot be regarded as truly representative.

The method proposed was to weigh the pieces before being sent to the finisher under such conditions that there was no possible doubt of the uniformity of the regain throughout the material. Such conditions are obviously unattainable in a hosiery factory. Usually no attempt is made to control the relative humidity. In the few factories in which humidifiers are installed the relative humidity is not controlled between sufficiently narrow limits to be helpful in such experiments. The pieces were therefore sent, as they left the knitting frames, to " Torridon " for conditioning and weighing in the humidity room. In this room the temperature is controlled to within 1°F. at 71°F., and the relative humidity within a range of 2% at 70%, any relative humidity between 50% and 95% being obtained by a simple setting of the controls, which are automatic and work night and day, including week-ends. During this conditioning operation the fabrics were suspended in loops on glass rods to give free access to the constantly circulating conditioned air, and they were weighed from time to time until they became constant to about 1 part in 5000. This usually required three to four days. When this constancy of weight was attained a small sample was cut from each and weighed accurately. The dry weight of this (as found in a conditioning oven giving results in very close accord with those of the Bradford Conditioning House) enabled the dry weight of the whole roll to be calculated. The pieces were then despatched to the finisher for the first operation.

This conditioning and weighing operation with the subsequent determination of the regain and total dry weight was repeated after each stage in the finishing process. Here the method became open to the objection that the result might not be true since the finishing was interrupted at each stage instead of going through the chain of operations in the usual manner. To overcome this legitimate objection some further rolls were conditioned and weighed, and their dry weights were determined. These were put through the finishing process in the usual manner without interruption and were returned to " Torridon" after the final operation of pressing.

During the discussions at the factory, the suggestion was made that the losses were incurred chiefly in the chlorination process. To test this point a roll of botany fabric was divided into four parts, which were conditioned and weighed as described above. The finisher was requested to omit the chlorination process from the first of these, to chlorinate the second mildly, to give the third the ordinary treatment, and to chlorinate the fourth excessively. In other respects the treatment was carried out in the ordinary way, the intervals between successive operations being no greater than usual. When finished, the four pieces were returned to " Torridon " for conditioning and determination of final dry weight. As will be seen in the results below the

suspicion cast upon the unshrinkable process is not confirmed. It is hoped to describe in a further publication some laboratory experiments on this subject.

Experimental Results.

The fabrics selected for experiment were :—

1. American Cotton.
2. Botany Wool Fabric, about 64's quality.
3. Fine Crossbred Wool Fabric, about 56's quality.
4. Botany Fabric similar to 2.

In each of the first three cases one part of material was finished without interruption, and a second piece was returned to us at the conclusion of each of the several stages in the finishing process, for conditioning and weighing.

The fourth was divided into four parts for the experiment on the effect of the degree of chlorination.

The results only are shown below and the utmost brevity has been aimed at in the presentation. In order to show how they have been obtained, the observations on the botany fabric, both those finished without interruption and those showing the losses at each stage, are shown in detail in the appendix. The calculations are also given. For convenience the summarised results are tabulated.

TABLE A.

PIECES FINISHED WITHOUT INTERRUPTION AT THE SEVERAL STAGES.

	Dry Weights. Before Scouring	Dry Weights. Finished	Loss or Gain	Conditioned Wts. Before Scouring	Conditioned Wts. Finished	Loss.
	gms.	gms.	%	gms.	gms.	%
1 American Cotton ...	4190	3934	6.12 loss	4512	4215	6.58
2 Botany	3820	3811	0.24 „	4406	4277	2.90
3 Crossbred	3580	3397	5.11 „	4074	3797	6.80
4 Botany. No Chlorn.	1830	1840	0.55 gain	2114	2061	2.50
Mild „	1950	1930	1.00 loss	2254	2173	3.61
Ord. „	1894	1887	0.37 „	2186	2125	2.79
Excess „	1927	1891	1.89 „	2228	2131	4.33

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The first column shows the dry weight of the piece "as knitted." The second shows the corresponding dry weight after finishing. The loss or gain in weight is shown in the third column, and is expressed as a percentage of the dry weight before scouring. This is obviously the best method of exhibiting the actual losses of material consequent upon finishing.

In the factory, however, the weights compared would not be dry weights, but weights at regains corresponding to the usual relative humidities. As pointed out above, the ordinary daily variations of relative humidity completely invalidate such comparison. If, however, the pieces before scouring and as "finished" could be weighed in an atmosphere of the same relative humidity, the recorded weights would then be of considerable value. This has been done in the fourth and fifth columns, which show respectively the weights before and after finishing, the weighings being made after the pieces had come into equilibrium with an atmosphere of 69% relative humidity at 71°F. These conditions are not greatly different from those prevailing in an ordinary heated room. The loss is shown in the sixth column and is expressed as a percentage of the weight before scouring in the atmosphere of 69% relative humidity.

It will be seen at once that the quantity of dry material removed in finishing is no greater than one would expect when the vigorous action upon wool and cotton of such substances as bleaching powder is borne in mind. The difference between the crossbred and botany in this respect is largely accounted for by the fact that the former has been spun in oil and the latter dry spun. These losses, however, appear to be far greater when the weights in an atmosphere of 69% relative humidity are considered. These apparent losses are of similar magnitude to those observed in practice. As will be seen more clearly below, this is due to the fact that in the finished state the hygroscopic capacity of the materials is found to be considerably reduced. This aspect of the problem will be dealt with subsequently.

Referring to the dry weights, it will be observed that the losses on the botany fabrics are small, and that in one case there is an actual gain in weight. An explanation suggested by laboratory experiments is that some of the substances used in the chlorination and bleaching processes (e.g., sulphur dioxide), are absorbed by the wool, or form additive compounds with it.

TABLE B.

PIECES CONDITIONED AND WEIGHED AT DIFFERENT STAGES IN THE FINISHING PROCESS.

	Stage.	Dry Weight.	Loss or Gain %	Conditioned Weight.	Loss or Gain.
		gms.	%	gms.	%
1 American Cotton	Before Scouring ...	3715	—	4000	—
	Scoured	3567	3.98 loss	3834	4.15 loss
	Bleached	3548	4.50 „	3811	4.73 „
	Tinted and Pressed ...	3542	4.65 „	3372	5.70 „
2 Botany	Before Scouring ...	3491	—	4031	—
	Scoured	3427	1.85 loss	3955	1.88 loss
	Chlorinated and Milled...	3451	1.16 „	3960	1.76 „
	Bleached and Pressed ...	3518	0.76 gain	3925	2.63 „
3 Crossbred	Before Scouring ...	3732	—	4269	—
	Scoured	3531	5.40 loss*	4072	4.62 loss
	Milled, etc.	3574	4.22 „	4058	4.94 „
	Bleached and Pressed ...	3584	3.97 „	4005	6.19 „

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* This loss is of the same order of magnitude as that shown in Table A.

The results here tabulated for the pieces conditioned and weighed at the different stages in the finishing processes correspond to 1, 2 and 3 in Table A, which were finished without interruption. The changes in weight are calculated as before as percentages of the weight before scouring. Again it is seen that the losses shown by the weights in the atmosphere of 69% relative humidity are greater than those shown by the dry weights. Further, it will be observed that up to the final stage, i.e. the pressing operation, the losses shown by the conditioned weights are roughly parallel to those shown by the dry weights, and that after pressing there is a considerable divergence. *This indicates clearly, as remarked above, that the power of absorbing and retaining moisture is impaired appreciably by the pressing operation,* and that the previous processes have little effect in this respect. In the case of the botany and crossbred pieces the weights strongly suggest either the absorption of the chemical substances used in bleaching or the formation of additive compounds.

A further interesting deduction from Tables A and B is that these results suggest that the chlorination and bleaching processes are not as readily controlled as is desirable. If the results were capable of accurate reproduction No. 2 and No. 4 with ordinary chlorination in Table A and No. 2 in Table B should show approximately the same loss or gain in weight. This is obviously not the case. Also, assuming that the principal losses are incurred in the chlorination process, the separate parts of No. 4 in Table A should show a regular gradation in

the changes in weight. This again is seen not to be the case. The laboratory experiments on chlorination, referred to above, suggest that the loss in weight is dependent upon the amount of chlorine taken up by the wool, but the relation is not that of simple proportionality.

The Relation between the Moisture Content and the Stages in the Finishing Process.

The outstanding result of the above experiments is that the operation of hot pressing causes a reduction in the hygroscopic capacity of the material. In view of this it was necessary further to investigate this matter. Samples of the materials taken from the rolls in all the available stages were exposed in the humidity room, which was maintained at 71°F. and 69% relative humidity. When the weights became constant the regains were calculated. These are shown below in Table C.

TABLE C.

PIECES FINISHED WITHOUT INTERRUPTION AT THE VARIOUS STAGES.

	Regain at 69% Relative Humidity. As Knitted.	Regain at 69% Relative Humidity. Finished.
	%	%
1 Cotton	7.68	7.17
2 Botany	15.40	12.25
3 Crossbred	14.05	11.80
4 Botany. No Chlorination	15.48	12.08
Mild "	15.60	12.60
Ord. "	15.45	12.45
Excess "	15.50	12.72

PIECES CONDITIONED AND WEIGHED AT VARIOUS STAGES IN THE FINISHING PROCESS.

	Regain at 69% Relative Humidity.			
	As Knitted.	Scoured.	Chlorinated, Bleached & Milled.	Pressed.
	%	%	%	%
1 Cotton	7.67	7.43	7.32	6.55
2 Botany	16.40	15.43	14.75	11.58
3 Crossbred	14.40	13.33	13.02	11.75

The first portion of the table shows the regain of the materials before scouring and after finishing. Nos. 2 and 4, being exactly similar wool, might be expected to have the same regain. It is suggested that the differences between these in the finished state might be due to different damping before pressing, variation in the temperature of the

press, or other similar factors. However, the striking result is that two pieces of the same fabric, one before scouring and the other finished, can be exposed within a few inches of one another and yet differ so largely in regain.

The second part of the table is interesting in that it shows the very small effect upon the hygroscopic capacity of the operations previous to pressing.

This was confirmed by a series of observations on some materials obtained from another source. To ensure a result of practical value, arrangements were made to extract a sample garment at the conclusion of each stage of the process from a batch going through in the usual way. These samples were weighed in the humidity room at two different relative humidities, the weights being allowed to become steady before changing the humidity. The dry weights were found and the regains were calculated. In this particular case it may be noted that the garments were cold pressed on wooden shapes, and it is interesting to observe that cold pressing involves no reduction of hygroscopic capacity.

TABLE D.

REGAINS OF WOOLLEN GARMENTS AT THE DIFFERENT STAGES IN THE FINISHING PROCESS.

State.	Regain at 79% Relative Humidity.	Regain at 58% Relative Humidity.
	%	%
Greasy...	18.14	13.97
Scoured	17.94	13.80
Chlorinated	16.88	13.16
Bleached	17.69	13.66
Finished (Cold Press)	17.67	13.72

The lowest regain is seen to be exhibited by the material after chlorination, but the subsequent processes largely restore the moisture absorbing powers.

In the main, therefore, these large scale experiments show clearly that the apparent losses in the finishing of Botany and Crossbred wool fabrics are very largely accounted for by the low regain of the finished

material which is due to hot pressing. Naturally these condition losses will be of much smaller importance in the case of cotton, the normal regains of which are only about one half of those of wool.

Extension of the Work by means of Small Scale Experiments under Practical Conditions.

In the foregoing experiments all the materials on which the losses were determined were finished by the same firm. It is therefore hardly justifiable to assume without further tests that the results are of general application. Consequently the following experiments were undertaken. They were confined to wool.

First Series of Experiments.

A number of small samples, chosen so as to be representative of the qualities and counts used in some branches of the underwear trade, were collected. These included :—

(a)	2/20	yarn	knitted	on	Cotton's Patent	Frame		24 g.
(b)	2/18	„	„	„	„	„	„	16 g.
(c)	2/35	„	„	„	Circular	Frame		24 g.
(d)	2/40	„	„	„	„	„		30 g.
(e)	2/93	„	„	into hose				39 g.

Wherever necessary, the edges of the pieces were carefully bound with wool to prevent loss by fraying or unravelling during finishing. The samples were exposed in the humidity room until the weights were steady. By drying out one piece from each of the lots before scouring, the regain of all could be found, and the original dry weights could be calculated. Several firms were then asked if they would finish these samples along with batches of their own materials of approximately similar qualities. Since many firms are naturally reluctant to furnish particulars of the processes they employ for chlorination and bleaching, the members undertaking the work for us were asked to supply only the barest outline of their method. This is shown in Table E below.

When the pieces were finished they were returned to " Torridon " and again exposed in the humidity room for their weights to become steady. The dry weight of each was then determined and the regain was calculated. A piece of unscoured material from each lot was exposed along with the finished materials and its regain was found. The regains in the finished state could thus be directly compared with that of the material previous to scouring.

TABLE E. RESULTS OF FIRST SERIES OF SMALL SCALE EXPERIMENTS.

Material.	Finisher.	Treatment.	Dry Weight. Before Scouring.	Dry Weight. Finished.	Change in Dry Weight (% of Dry Weight before scouring).	Regain.
			grms.	grms.	%	%
		Sample Unscoured.				14.29
(a)	Firm A	Scoured, Chlorinated, Peroxide Bleached, Pressed ...	94.33	90.60	3.95 loss	11.40
	Firm B	„ „ Sulphur Bleached, Pressed ...	96.45	96.54	0.09 „	10.24
	Firm C	„ „ Peroxide Bleached, Pressed ...	95.76	93.33	2.54 „	12.66
		Sample Unscoured.				14.40
(b)	Firm A	As A above	64.08	61.88	3.43 loss	11.63
	Firm B	„ B „	64.59	62.59	3.10 „	9.97
	Firm C	„ C „	65.10	52.89	18.75 „	12.96
		Sample Unscoured.				13.23
(c)	Firm A	As A above	43.01	39.11	9.07 loss	11.85
	Firm B	„ B „	71.90	66.09	8.10 „	10.49
		Sample Unscoured.				14.13
(d)	Firm A	As A above	60.91	58.91	3.29 loss	11.44
	Firm B	„ B „	108.20	107.50	0.65 „	10.60
		Sample Unscoured				14.03
(e)	Firm A	As A above	25.22	24.24	3.96 loss	11.07
	Firm B	„ B „	24.54	24.30	0.98 „	10.09
	Firm C	„ C „	24.23	22.72	6.23 „	12.15

This table requires but little explanation. The dry weight before scouring is contrasted with the dry weight in the finished state, and the change in dry weight is expressed as a percentage of the original dry weight. Considering these results in general it is seen that the changes in dry weight are of the same order as those observed in the large scale experiments, and it is therefore reasonable to assume that the results of the large scale tests may be regarded as typical of hosiery finishing

losses. The percentage loss of conditioned weight, which is not given in the above table, is readily calculable. It is approximately equal to the percentage loss of dry weight plus the loss of percentage regain. Thus sample (a) finished by Firm A suffered a loss of 3.95% dry weight and 2.89% regain. The loss of conditioned weight was therefore about 6.8%.

There are, however, several points to which attention might be directed. Firms A and C use a peroxide bleaching process, while Firm B uses the sulphur dioxide bleach. In each of the five cases the loss in the sample finished by Firm B is the least.

The regains bring out another interesting point. The pressing operation by Firm B has caused the greatest reduction of hygroscopic capacity. That of Firm A is less drastic in its effect, and that of Firm C is still less so. This question will be dealt with in a subsequent part of this work on hosiery finishing.

The abnormally large loss of sample (b) finished by Firm C requires further comment. The first suggestion made was, naturally, that an error had crept into the measurements. Careful checking ruled out this explanation, as the figures proved to be correct. In order to be quite certain, the wales and courses were counted and weight per stitch was estimated. After making due allowance for the regain, this was compared with the weight per stitch of the similar samples finished by the other firms. By this method the loss was estimated at 18.25%, the agreement with the direct measurement being as close as could be expected. When this was brought to the notice of Firm C, it was suggested that the small sample had been left in the bath when the batch of goods with which it was treated was removed. This seemed to provide the most probable explanation.

Second Series of Experiments.

In the discussion of the results of the above series of tests, one of the firms suggested some further experiments on somewhat different lines. The object was to determine the losses due to :—

(a) Scouring.

(b) Chlorinating.

(c) Bleaching.

(d) Finishing completely.

Two qualities of fabric, knitted on Cotton's Patent Frames from 2/19 and 2/28 yarns respectively were selected. To each firm four pieces of each quality were sent. Of each set of four

No. 1 was to be scoured only.

No. 2 was to be scoured and chlorinated.

No. 3 was to be scoured, chlorinated and bleached.

No. 4 was to be completely finished.

Previous to sending out, all the samples were conditioned and weighed in the humidity room. From the observed weights and the regains of similar pieces exposed at the same time, the original dry weights of all the pieces could be readily calculated. On the return of the samples, they were hung in the humidity room until the weights were steady, and the dry weights were then determined. It is clear that No. 1 gives the scouring loss, No. 2 gives the loss due to scouring and chlorinating, No. 3 the loss due to scouring, chlorinating and bleaching, and No. 4 the complete loss. From the steady weights and the dry weights the regains were calculated. An unscoured piece of each quality and of known dry weight exposed alongside the finished samples enabled the direct comparison of regains before scouring and after finishing to be made. Tables F and G show respectively the results of the experiments on the fabrics knitted from the 2/19 and 2/28 yarns.

TABLE F.

TESTS ON FABRIC KNITTED FROM 2/19 YARN.

Finisher	No. of Piece.	Treatment.	Dry Weight. Before Scouring.	Dry Weight. After Treatment.	Change in Dry Weight (% of Dry Wt. before Scouring).	Regain.
			gms.	gms.	%	%
Firm A	1	Scoured and	49.71	49.00	1.45 loss	14.04
	2	Chlorinated	50.88	50.56	0.63 „	13.71
	3	Scoured, Chlorinated, and Bleached ...	49.95	49.40	1.10 „	14.06
	4	Completely Finished ...	49.66	49.12	1.09 „	12.98
Firm C	1	Scoured	46.55	46.60	0.11 gain	14.29
	2	Scoured and Chlorinated	47.42	46.46	2.03 loss	13.50
	3	Scoured, Chlorinated and Bleached ...	48.07	46.34	3.60 „	13.37
	4	Completely Finished ...	45.06	42.51	5.66 „	13.78
Firm D	1	Scoured	45.28	45.13	0.33 loss	14.62
	2	Scoured and Chlorinated	46.60	44.47	4.57 „	14.61
	3	Scoured, Chlorinated and Bleached... ...	48.98	47.79	2.43 „	12.90
	4	Completely Finished ...	48.43	47.50	1.92 „	11.23
		Before Scouring ...				13.64

Table G.

Tests on Fabric Knitted from 2/28 Yarn.

Finisher	No. of Piece.	Treatment.	Dry Weight. Before Scouring.	Dry Weight. After Treatment.	Change in Dry Weight (% of Dry Wt. before Scouring).	Regain.
			gms.	gms.	%	%
Firm A	1	Scoured and Chlorinated	53.75	53.35	0.74 loss	13.50
	2	Scoured and Chlorinated	49.50	49.16	0.69 „	13.75
	3	Scoured, Chlorinated and Bleached ...	54.13	53.74	0.72 „	13.16
	4	Completely Finished ...	51.64	51.09	1.06 „	13.24
Firm C	1	Scoured	55.51	55.00	0.92 loss	14.35
	2	Scoured and Chlorinated	54.42	53.59	1.52 „	13.16
	3	Scoured, Chlorinated and Bleached ...	52.10	49.45	5.09 „	13.97
	4	Completely Finished ...	53.06	50.44	4.94 „	13.00
Firm D	1	Scoured	52.67	52.36	0.59 loss	14.71
	2	Scoured and Chlorinated	53.16	50.84	4.36 „	14.52
	3	Scoured, Chlorinated and Bleached ...	50.42	49.75	1.33 „	13.02
	4	Completely Finished ...	48.28	47.25	2.14 „	11.22
		Before Scouring ...				13.50

Firm A by accident chlorinated No. 1 as well as No. 2. It would be expected, therefore, that Nos. 1 and 2 would show approximately the same loss. Whilst this is the case with the fabric knitted from the 2/28 yarn it is clearly not so with the other material. This has been interpreted as a proof of the inherent difficulties in the application of the chlorination process. Further evidence supporting this view is provided by Nos. 3 and 4 in each lot of samples. Since No. 4 differs from No. 3 only in the mechanical operation of pressing, which can involve no change of dry weight, these two samples should show the same loss. An examination of the tables reveals four cases out of six in which these quantities which should be alike show considerable differences.

In the process employed by Firms A and C, the total loss due to scouring, chlorinating, and bleaching is greater than the loss due to scouring and chlorinating; in other words the bleaching process involves a loss of dry material. The process of Firm D gives the opposite results, suggesting a difference in the nature of the bleaching process.

A set of these samples was also sent to a fourth firm, but they were unfortunately not treated in accordance with the programme accompanying the materials. To include the results would merely confuse the issues here, but even these afford additional evidence of the difficulty of accurate repetition of results in the processes of chlorination and bleaching.

On the whole it may be taken that since these experiments on small samples conducted under practical conditions confirm those on the large scale, the losses determined in the whole group of experiments may be regarded as fairly representative of the losses in hosiery finishing.

Acknowledgments.

It will be at once apparent to all that research of this character is impossible without the co-operation of the trade. Practical conditions can be imitated in the laboratory but the results do not usually convince practical men. The hosiery manufacturers and finishers in the following list have encouraged the work by their interest in it, and have assisted by providing materials and finishing the same or arranging for their particular finishers to do so.

The thanks of the Association for their help are therefore accorded to :—

Messrs. Hawley & Johnson Ltd., Leicester.
Messrs. Innes Henderson & Co. Ltd., Hawick.
Messrs. J. B. Lewis & Co. Ltd., Nottingham.
Messrs. Murray Bros., Nottingham.
Messrs. Peter Scott & Co. Ltd., Hawick.
Messrs. Wolsey Ltd., Leicester.

Conclusions.

The main conclusion to be drawn from these experiments is that the apparent losses in hosiery finishing are, in general, largely accounted for by the reduced hygroscopic capacity of hot pressed fabrics.

In other words, hot pressing, though involving no removal of wool substance, reduces the saleable weight, because the fabric absorbs less moisture.

The second important inference is that results in hosiery finishing are not easily reproduced accurately. This is probably mainly due to the character of the chemical reactions involved.

These experiments do not provide an unqualified confirmation of the suspicion that the main losses are incurred in the chlorination process. If the fabrics are not severely chlorinated the losses experienced in the process are not excessive. The bleaching process adopted by some firms results in losses of the same order as those due to chlorination.

Note.

In the succeeding parts of this paper it is hoped to describe experiments bearing on the nature of the reduction of hygroscopic capacity due to hot pressing and a proposed explanation of the effect. A method of finishing, suitable for certain classes of materials and not entailing low hygroscopic capacity in the finished materials will be suggested.

APPENDIX.

Example of the Observations made in the determination of the losses of hosiery fabrics in the finishing processes together with their reduction.

(1) **Botany Fabric.**—Finished without interruption at the several stages. (See Table A, line 2).

(a) **Actual Losses of Dry Material.**

Steady Weight* of piece before scouring	4400.5	grams.
„ „ sample retained	74.45	„

The piece weighing 4400.5 grams was sent for finishing.

Steady Weight of piece when finished	4134	grams.
„ „ sample retained	117.30	„

The dry weights of the samples were determined at a later date, the pieces again being allowed to become steady (at a somewhat different relative humidity) before removing the portion actually dried out.**

Sample of material before scouring.

Steady weight 74.76 grams.

Weight removed for drying 19.43 grams.

Dry weight corresponding to 19.43 grams = 16.80 grams.

$\therefore$ Dry Weight of sample $= \dfrac{74.76}{19.43} \times 16.80 = 64.55$ grams.

$\therefore$ Dry Weight of whole piece before scouring $= \dfrac{4400.5}{74.45} \times 64.55 = 3820$ grams.

Sample of Finished Material. Steady Weight	121.64	grams.
Weight removed for drying	12.44	„
Dry Weight corresponding to 12.44 grams	= 11.06	„
$\therefore$ Dry Weight of Sample $= \dfrac{121.64}{12.44} \times 11.06$	= 108.1	„
$\therefore$ Dry Weight of whole piece when finished $= \dfrac{4134}{117.30} \times 108.1$	= 3811	„

$\therefore$ Actual Loss $= \dfrac{3820-3811}{3820} \times 100 = 0.24\%$ of the dry weight before scouring.

(b) **Apparent Losses at 71°F. and 69% Relative Humidity.**

The weights at 69% relative humidity were deduced from observations on the remainder of the sample pieces after removal of a part for dry weight determination.

* As described in the text the steady weight is the last of a series of weighings which was continued until successive observations differed by not more than 1 part in 5000.

** In all these experiments a portion only of the sample piece was actually dried out. This method was adopted because the drying oven available gave unreliable results with large samples. In order to maintain the accuracy of the work a more sensitive balance than that supplied with the oven was employed. A number of tests on tops, yarns and knitted fabrics were made specially to compare the results of regain tests in this oven with those determined by the Bradford Conditioning House. The agreement when small pieces were dried was highly satisfactory.

Material before scouring.

Weight of sample after removing part for drying out ... = 55.33 grams.

" this at 71°F. and 69% relative humidity ... = 55.15 "

$\therefore$ Weight of whole piece $= \frac{55.15}{55.33} \times 74.76 \times \frac{4400.5}{74.45}$ ... ... $= 4406$ "

Finished Material.

Weight of sample after removing part for drying out ... $= 109.20$ grams.

" this at 71°F. and 69% relative humidity ... $= 108.94$ "

$\therefore$ Weight of whole piece at 71°F. and 69% relative humidity

$$= \frac{108.94}{109.20} \times 121.64 \times \frac{4134}{117.30} \ldots \quad \ldots \quad = 4278 \text{ "}$$

$\therefore$ Apparent loss at 69% relative humidity $= \frac{4046—4278}{4406} \times 100$

$= 2.90\%$ of the weight at 69% before scouring.

(2) **Botany Fabric.**—Losses at the several stages in the Finishing Processes (see Table B).

(a) **Actual Losses of Dry Material.**

Steady Weight of piece before scouring ... ... $= 4006.5$ grams.

" " sample retained ... ... $= 97.28$ "

4006.5 grams sent away for scouring.

Steady Weight of scoured piece ... ... $= 3876.5$ grams.

" " sample retained ... ... $= 94.90$ "

3781.6 grams sent for chlorination and milling.

Steady Weight of chlorinated piece ... ... $= 3838$ grams.

" " sample retained ... ... $= 105.25$ "

3732.75 grams sent for bleaching and pressing.

Steady Weight of finished piece ... ... $= 3708.1$ grams.

" " sample retained ... ... $= 191.67$ "

The sample retained from the roll before scouring when got into a steady state for determination of dry weight weighed ... ... 98.22 grams.

Weight of piece cut away for drying out ... ... $= 22.52$ "

Dry Weight corresponding to 22.52 grams ... ... $= 19.44$ "

$\therefore$ Dry Weight of Sample $= \frac{98.22}{22.52} \times 19.44$ ... ... $= 84.76$ "

$\therefore$ Dry Weight of piece sent for scouring $= \frac{4006.5}{97.28} \times 84.76$ ... $= 3491$ "

Similarly

Dry Weight of sample after scouring $= \frac{97.02}{18.18} \times 15.72$ ... $= 83.90$ "

& " " piece " " $= \frac{3876.5}{94.90} \times 8390$ ... $= 3427$ "

Dry Weight of piece sent for chlorination ... ... $= 3343.1$ grams.

Similarly

Dry Weight of sample after chlorination $= \frac{106.17}{19.85} \times 17.26$ $= 92.28$ grams.

" " piece " " $= \frac{3838}{105.25} \times 92.28$ $= 3366$ "

Dry Weight sent for bleaching and pressing ... ... $= 3273.7$ grams.

Similarly Dry Weight* of sample from finished material

$$= \frac{191.67}{186.51} \times \frac{187.68}{18.05} \times 16.15 \ldots \quad \ldots \quad = 172.5 \text{ "}$$

* Two pieces removed from this sample.

Dry Weight of finished roll $= \frac{3708.1}{191.67} \times 172.5$ ... ... $= 3338$ grams.

Hence Scouring Loss $= \frac{3491-3427}{3491} \times 100 = 1.85\%$ of dry weight before scouring.

$$\text{Loss due to scouring and chlorinating} = \frac{3491-\left(\frac{3427}{3343} \times 3366\right)}{3491} \times 100$$

$= \frac{3491-3451}{3491} \times 100 = 1.16\%$ of dry weight before scouring.

$$\text{Gain due to complete finishing} = \frac{\left(\frac{3427}{3343} \times \frac{3366}{3273.3} \times 3338\right)-3491}{3491} \times 100$$

$= \frac{3518-3491}{3491} \times 100 = 0.76\%$ of the dry weight before scouring.

(b) Apparent loss at 71°F. and 69% relative humidity.

Weight of sample before scouring after removing part for drying out ... ... = 75.70 grams.

Weight of this at 71°F. and 69% relative humidity ... = 75.44 „

∴ Weight of whole piece before scouring at 71°F. and 69% relative humidity

$= \frac{98.22}{75.70} \times 75.44 \times \frac{4006.5}{97.28}$ ... ... $= 4031$ grams.

4031 grams (71°F. and 69%) sent for scouring.

Similarly Weight of piece after scouring at 71°F. and 69% relative humidity

$= \frac{97.02}{78.84} \times 78.67 \times \frac{3876.5}{94.90} = 3955$ grams.

3858 grams (71°F. and 69%) sent for chlorination.

Similarly Weight at 71°F. and 69% relative humidity after chlorination

$= \frac{106.17}{86.32} \times 86.11 \times \frac{3838}{105.25} = 3863$ grams.

3757 grams (71°F. and 69%) sent for bleaching and pressing.

Similarly Weight at 71°F. and 69% relative humidity of finished roll

$= \frac{187.68}{169.63} \times 169.39 \times \frac{191.67}{186.51} \times \frac{3708.1}{191.67} = 3724$ grams.

Hence Scouring Loss $= \frac{4031-3955}{4031} \times 100 = 1.88\%$ of weight (71°F. and 69%) before scouring.

$$\text{Loss due to scouring and chlorinating} = \frac{4031-\left(\frac{3863}{3858} \times 3955\right)}{4031} \times 100$$

$= \frac{4031-3960}{4031} \times 100 = 1.76\%$ of weight (71°F. and 69%) before scouring.

$$\text{Loss to complete Finishing} = \frac{4031-\left(3724 \times \frac{3863}{3757} \times \frac{3955}{3858}\right)}{4031} \times 100$$

$= \frac{4031-3925}{4031} \times 100 = 2.63\%$ of weight (71°F. and 69%) before scouring.

Part II.

The
Effect of Finishing Processes
on the Regain of Hosiery Material

1. INTRODUCTION.

Part I of this paper dealt with the measurement of the loss of weight occurring during the finishing of hosiery material. These losses were calculated in two ways (1) by comparing the *dry* weights before and after treatment, (2) by comparing similarly the steady weights attained (before and after treatment) in an atmosphere of known humidity and temperature. It was found that the percentage loss as calculated by the second method was in general much greater than that calculated by the first method.

The loss of weight in hosiery finishing is therefore largely due to a loss in the power of absorbing moisture, and not to actual loss of dry material. Moreover this loss of hygroscopic capacity was shown to be due almost entirely to one stage of the finishing process, viz., hot-pressing. The regain of the fabric was found to be reduced by amounts varying from 1% to 3½%.

The present paper deals with a number of points arising out of this question of the reduced hygroscopic capacity of finished hosiery fabrics.

In Section 2 is given a brief description of the different methods of producing a " finish " on hosiery fabrics. No attempt has been made to give a detailed description of the different presses. All that has been done has been to give some idea of the thermal and mechanical treatment given to the material in each case, with a view to rendering comprehensible certain subsequent portions of the paper.

Section 3 gives the results of experiments conducted on material hot-pressed by different firms. It is shown that in practically all cases there is a considerable reduction in the hygroscopic capacity, so that the effect is not due to any peculiarity in method of one particular firm.

Section 4 deals with the effect of other processes which are used to produce a " finish." It is shown that other methods cause a much smaller effect on the hygroscopic capacity than does hot pressing.

The next three sections (5, 6 and 7) are concerned with finding an explanation of this effect and of the remarkable difference between hot-pressing and other finishing processes.

Section 5 deals with the question of the permanence of the low hygroscopic capacity, which is shown to persist throughout extreme changes of atmospheric humidity extending over several months. On the other hand actual wetting is shown to restore to a great extent the original hygroscopic capacity.

In Section 6 are described a number of laboratory experiments in which an attempt was made to subject the fibre to a treatment such as would produce as large an effect on the hygroscopic capacity as is produced by hot pressing.

In Section 7 a review is made of all the facts relative to the effect and of their relation to certain theoretical considerations, and finally an explanation of the effect is given. To test the accuracy of this explanation a certain crucial experiment is carried out and found to give a result which affords a convincing proof of the soundness of our explanation.

The last section (8) deals briefly with the question of hosiery losses as estimated in the factory and with that of the standard of regain for hosiery goods.

In Part III. of this work we shall consider the question of finishing hosiery material so as to avoid any large loss of hygroscopic capacity.

The thanks of the Association are accorded to the following firms for their generous help in these experiments.

Messrs. Hawley & Johnson Ltd., Leicester.

Messrs. Hewitt, Haigh & Wilson, Leeds.

Messrs. Innes, Henderson & Co. Ltd., Hawick.

Messrs. T. G. Hirst, Leicester.

Messrs. J. B. Lewis & Son Ltd., Nottingham.

Messrs. Murray Bros., Nottingham.

Messrs. Peter Scott & Co. Ltd., Hawick.

Messrs. Turnbull, Hawick.

Messrs. Wolsey Ltd., Leicester.

2. METHODS OF IMPARTING "FINISH."

The process of imparting "finish" consists essentially of the subjecting of the material to mechanical constraint while in a moist condition either hot or cold. There are considerable differences with regard both to the nature of the mechanical constraint and to the temperature conditions. The following are brief descriptions of the different methods.

The Pegg Press.

The material is stretched on boards and subjected to mechanical pressure between the smooth bare faces of two steam-heated iron boxes. The lower box is fixed and forms a table on which the goods are laid. The upper box can be raised and lowered by means of a screw worked by a long lever weighted at its ends with iron balls. This press is the one most commonly used in the underwear trade, particularly in the section dealing with "cut" garments.

The Hoffman Press.

Of this press there are a number of models. The type generally used consists of a metal steam box with a perforated base, the box being mounted on an arm hinged to the press frame at the back so that it can be readily raised or lowered. The perforated base is covered with a pad of sheeting, and the box is fed with steam through a reducing valve and water trap. The material to be pressed is placed on the iron table, which is also covered with a pad, and the box is brought down upon it, and the valve opened. The actual mechanical pressure applied is small. After a few seconds the steam is shut off, and the box is raised. There is usually sufficient heat in the lower part to render the material dry enough for removal.

In the latest models the iron table is replaced by a fixed steam box similar to the upper one, and there is a steam injector so that after sufficient exposure to the steam, air can be drawn through the boxes and the material while the light pressure is still applied. In this form the action of the press recalls the wrapper-blowing process practised in the woollen and worsted cloth trades.

The Cold Press.

This press is the same as that employed in the cloth trade. Pressure is applied by hydraulic power or by a screw. If desired, very gentle heat can be applied by iron plates previously heated in a steam oven or by electric press papers. The garments pressed in this way are boarded.

Drying on Shapes.

The garments are placed on boards or metal shapes which are then dried in a steam heated chamber usually at a temperature not greater than 200°F. In this method the mechanical treatment is very gentle, the fabric being held at a small tension and subjected to a slight pressure at the surface in contact with the shape.

The "Paramount" Finishing Machine.

This consists of a series of hollow metal shapes (e.g., for hose), which are heated internally with steam. The damped goods are dried on these shapes. Some observations on hose finished in this way appear in Section 4.

Calenders.

A simple calendering (passage between rollers) is generally considered as not so suitable for woollen goods as for cotton. The great intensity of the pressure over the small area of contact of the rollers produces too much of a flattening effect. There are, however, numbers of what may be termed modified calenders on the market, in which an effort is made to produce a more suitable mechanical treatment. Thus in the Hunt Machine the tubular fabric is treated, while on a "shape," to the "ironing" action of three pairs of rollers, and finally to the action of a single pair of nip rollers. The preliminary damping is done by means of steam jets. Other forms of modified calenders are the Thomlinson and Grösinger machines.

3. A COMPARISON OF THE EFFECT OF HOT-PRESSING BY DIFFERENT FINISHERS.

The results of a number of experiments on the regain of different samples before and after finishing by different firms are shown in Table I. Most of the results relate to samples which were sub-divided, one portion being retained and the others sent to different firms for hot-pressing. In the table are included some data from Part I. which have been included for purposes of comparison. The regains of the unfinished and finished samples were compared after they had been in the humidity room side by side for several days (till their weights had become constant). In all but two instances the room was maintained at a medium humidity, giving regains for the unfinished material of from 13 to 15%.

TABLE I.

Material*.	Firm.	Regain. Unscoured.†	Finished.	Difference.
Botany	J	15.40	12.25	3.15
Crossbred	„	14.05	11.80	2.25
Botany —not chlorinated	„	15.48	12.05	3.43
„ mild chlorination... ...	„	15.60	12.60	3.00
„ ordinary „	„	15.45	12.45	3.00
„ excessive „	„	15.50	12.72	2.78
Botany	„	15.40	11.58	2.82
Crossbred	„	15.40	11.75	2.65
Botany (64's)*	C	17.60†	17.22	0.38
Crossbred (40's)*	„	18.59†	17.25	1.34
Knitted from 1/24's yarn, 60's quality	G	14.25†	11.32	2.93
Knitted from 2/28's yarn	C	13.50	13.00	0.50
	H	„	11.60	1.90
	A	„	13.24	0.26
	D	„	11.22	2.28
Knitted from 2/19's yarn	C	13.64	13.78	0.14gain
	H	„	12.22	1.42 loss
	A	„	12.98	0.66
	D	„	11.23	2.41
Knitted from 2/20's yarn	C	14.29	12.66	1.63
	H	„	10.50	3.79
	A	„	11.40	2.89
	B	„	10.24	4.05
Knitted from 2/18's yarn	C	14.40	12.96	1.44
	H	„	10.39	4.01
	A	„	11.63	2.77
	B	„	9.97	4.43
Knitted from 2/36's yarn	H	13.23	10.52	2.71
	A	„	11.85	1.39
	B	„	10.49	2.74
Knitted from 2/40's yarn	H	14.13	10.25	3.88
	A	„	11.44	2.69
	D	„	10.60	3.53
Hose knitted from 2/93's yarn ...	C	14.03	12.15	1.88
	H	„	11.70	2.33
	A	„	11.07	2.96
	B	„	10.09	3.94
Knitted from 1/24's yarn	H	14.05†	10.26	3.79
	A	„	11.13	2.92

* All the results indicate that the reduction of regain is independent of quality.
† Unscoured in most cases, but those marked † scoured.

These results show the effect is not confined to the work of a single firm. The magnitude of the effect varies considerably. This is probably due in some cases to difference in the installations. Thus in one case a press will be fed with steam coming through a good length of unlagged pipe, whilst another will have the shortest possible connection to the steam pipe—the feed pipe being moreover efficiently lagged. There are other differences, e.g., time of pressing, initial water content, etc., which will influence the results. The later sections of this paper show how these factors can influence the result.

4. THE EFFECT OF OTHER FINISHING PROCESSES.

In Table II. are given the results of a series of observations on material before and after finishing on the Hoffman Press.

TABLE II.
(HOFFMAN PRESS).

Material.	Firm.	Regain. Scoured.	Finished.	Difference.
Knitted from 1/24's yarn, 60's quality	K G	13.60 14.25	12.67 13.48	0.93 0.77
Ribbed Fabric 2/18's yarn	K	12.63	12.40	0.53
Ribbed Fabric 2/26's yarn	K	12.42	11.77	0.65
64's Botany Fabric	K	14.10	13.56	0.54

It will be seen that this method of pressing has only a small effect on the hygroscopic capacity.

In Table III. are given results relating to the Cloth Press (with gentle heat), and the Cold Press. The former result is compared not with an unfinished sample, but with a portion of the same fabric finished in the Pegg Press.

TABLE III.

Material.	Firm.	Method.	Regain. Scoured.	Finished.	Difference.
Crossbred	L J	Cloth Press Pegg Press	— —	13.17 11.76	1.41
Knitted from 1/24's yarn, 60's quality ...	—	Cold Press	13.29	13.44	0.15 increase

As would be expected, the cold-pressing caused no diminution of the hygroscopic capacity.

Some data relative to the effect of the Paramount Process are given in Section 5.

5. THE DEGREE OF PERMANENCE OF THE REDUCED HYGROSCOPIC CAPACITY.

The reduced hygroscopic capacity resulting from hot pressing is evidently due to some change in the internal structure of the fibre. Now the wool fibre possesses a somewhat remarkable power of slow recovery from ordinary mechanical deformations. It is not inconceivable, therefore, that the change produced by hot pressing may be only temporary, and that in time there may be an increase in the hygroscopic capacity, or even an almost perfect recovery of the original capacity.

This question has been definitely settled by observations extending over two years. When this work was first begun, samples both of unscoured and of completely finished Botany fabric came into our possession. Regain observations were made at humidities ranging from 50% to 95%, the pieces being kept in close proximity. During the time that these samples have been under observation they have been through several cycles of humidity changes, but the difference in regain still persists.* This is all the more striking since exposure at humidities over 90% tends to remove " finish."

* See Table XVII., p. 37.

There is, however, a more drastic method of affecting the internal state of a fibre than by merely exposing to a high atmospheric humidity. This is by actually *wetting* a fibre. The results of a series of experiments on wetting the fabric are shown in Table IV. A piece of finished Botany fabric was divided into four parts, A, B, C and D, which were treated as shown in the second column of the table. The pieces were then exposed in the humidity room until their weights became constant. They were then dried out to determine the regain (which is given in the third column).

TABLE IV.

Part.	Treatment.	Regain %.	Increase of regain due to wetting.
A	Preserved unchanged	11.88	—
B	Exposed to steam from kettle spout	13.16	1.28
C	Laid between wet cotton cloth for one hour ...	13.80	1.98
D	Immersed in water and thoroughly wet ...	13.74	1.86

It will be seen that the impaired hygroscopic capacity is largely restored by wetting. It may be pointed out that before the wetted samples were replaced in the humidity room they were dried to a weight less than their final equilibrium weight. This showed that we were dealing with a true equilibrium effect, and that the increased regain was not due to abnormally slow drying after wetting.

This method of restoring the hygroscopic capacity is not, of course, a practicable method of obviating the consequent apparent loss of material. It has, however, an important bearing on the question of the shrinking of cloth and its effect on the regain of pieces.

Table V. contains data relative to the effect of wetting of a number of samples of botany fabric which had been dyed and hot pressed. The dyeing was done with an object extraneous to the subject of this paper. It was thought, however, that the pieces could be used for the purpose of the present investigation. They had already been weighed when in equilibrium with a standard atmosphere. They were wetted out, allowed to dry without heat in the laboratory, and then replaced in the humidity room for the determination of their equilibrium condition. In the case of some of the samples the effect of a second wetting out was investigated. In the first column of the table is given for reference, the colour of the specimen (and in some cases details as to the dye used).

TABLE V.

Colour (or Dye).	Regain %.		
	As pressed.	After First wetting.	After Second wetting.
Crystal Scarlet	10.24	13.52	—
Crystal Scarlet, stripped and re-dyed Crystal Scarlet	10.85	13.08	—
Phenylamin Black	10.54	13.74	—
Hæmatine on Chrome	11.42	14.30	15.06
Putty	10.68	13.15	—
Grey	10.20	13.24	—
Tobac	10.23	13.20	—
Navy	11.50	14.50	15.00
Green	10.20	12.83	13.10
Saxe	10.89	13.50	—
Coral	11.75	14.07	—
Nigger	10.43	12.71	13.33

It will be seen that the process of restoration of the hygroscopic capacity is by no means complete after the first wetting. An appreciable further restoration occurs after a second wetting.

The two following tables contain data relating to a dozen stockings made from yarn of the "heather mixture" type, the quality of the wool being about 60's. Six of these were finished by the "Paramount" process, and six in the Pegg Press. All the regain measurements were made subsequent to finishing. The steady weights of the stockings were determined at two humidities (59% and 80%). Each set of 6 stockings was divided into three sets of two which were respectively

(a) preserved uncharged, (b) placed in a wet cotton cloth for one hour, (c) dried at 230°F. and then placed in a wet cotton cloth for one hour. The equilibrium regains were then determined at 80% humidity. The 36 values of the regain thus obtained afford data (1) as to the difference in hygroscopic capacity of Paramount finished and hot-pressed goods (see Table VI.), (2) as to the recovery on wetting (and therefore as to the effect of the finishing) (see Table VIa.)

TABLE VI.

REGAINS OF GOODS FINISHED BY TWO METHODS.

Paramount Finished.		Hot-pressed.	
In 59% Atmosphere.	In 80% Atmosphere.	In 59% Atmosphere.	In 80% Atmosphere.
11.92	17.36 (17.32)	10.05	15.63 (15.85)
12.15	17.54 (17.45)	9.90	15.63 (15.88)
12.04	17.48	10.15	15.60
11.89	17.30	10.04	15.62
12.15	17.36	10.48	16.25
12.39	17.26	10.31	16.13

The numbers in brackets relate to the stockings which were preserved uncharged and tested in the 80% atmosphere at the same time as the treated samples.

TABLE VIA.

REGAINS IN 80% ATMOSPHERE.

Treatment.	Paramount Finished.		Hot-pressed.	
	Before Treatment.	After.	Before Treatment.	After.
Placed in wet cotton cloth for 1 hr. ...	17.48 17.30	18.64 18.54	15.60 15.62	18.42 18.43
Dried at 230°F. then placed in wet cotton cloth for 1 hr. ...	17.36 17.26	18.71 18.96	16.25 16.13	18.81 18.75

These data illustrate a number of points in addition to that with which the present section is immediately concerned (the restoration, by wetting out, of the impaired hygroscopic capacity of hot pressed material). Table VII. contains the results relating to the 80% atmosphere averaged in four classes resulting from the two twofold divisions based on finish and treatment.

TABLE VII.

REGAINS IN ATMOSPHERE OF 80% HUMIDITY.

	Paramount.	Pegg Press.	Difference due to difference in finish.
Before treatment	17.38	15.81	2.57
After treatment	18.71	18.60	0.11
Difference due to treatment	1.33	2.79	

It will be noticed from Table VI. that the process of wetting, whether preceded by drying or not, brings all the samples to very nearly the same hygroscopic capacity. On the average the Pegg-pressed samples come to within 0.11 of those which had been finished on the Paramount. Moreover the difference, small as it is, is in the direction which we should expect when we consider that the restoration is probably not complete.

We see also from these results that the " Paramount " process causes a much smaller loss of hygroscopic capacity than the Pegg Press. The mean difference of regain in the 80% atmosphere is 2.57 (as shown in Table VII.), and in the 59% atmosphere 1.94.

The figures throw some light on another point which is of importance in relation to the accuracy of experimental work on regain. There are many sources of error in such work, and it is desirable to form some estimate of the magnitude of the errors involved. The effect of errors of weighing is quite negligible. Even with small samples weighing about 50 grm. which were weighed to .01 grm., the maximum possible error in weighing would only cause an error of about 0.02 in the regain. The most serious source of experimental error is the lack of absolute constancy of the humidity room. This will be most serious at high humidities where the regain increases very rapidly with the humidity. So far as it is possible to estimate it, the possible error at 80% humidity is of the order of .2% regain. The most serious discrepancy in Table VI. is the difference between the regain in the 80% atmosphere of the hot pressed samples which were preserved unchanged (0.22 and 0.26). These differences, though much too small to cast any suspicion on any general conclusion arrived at in this work, are extreme instances representing probably the combined effects of two or more errors acting in the same direction.

6. AN EXPERIMENTAL INVESTIGATION OF THE EFFECT OF VARIOUS KINDS OF TREATMENT ON THE HYGROSCOPIC CAPACITY.

The first step towards understanding the nature of the effect produced by hot pressing is to try to produce a similar effect by treat-

ment in the laboratory. There seems to be practically no information available as to the influence of even the most ordinary treatment (e.g., ironing, drying) on the hygroscopic capacity. Table VIII. contains the results of some experiments involving such treatment conducted with some tubular fabric knitted at Torridon on a stocking frame from 1/24's yarn of 60's quality. A large quantity of this was knitted up and scoured, to form a stock for this and other series of experiments. The humidity of the atmosphere in which the different samples were tested, was not always the same, as changes in the controlled humidity of the humidity room were necessary for other researches. This variation is, however, of no moment since in each group the regain of an untreated piece is shown along with that of the treated pieces.

TABLE VIII.

Sample.	Treatment.		Equilibrium Regain.	Decrease caused by treatment.
1	Untreated		15.03	—
2	Boiled in water for one hour ...		15.13	0.10 increase
3	Dried in Conditioning Oven for one hour	@ 200°F.	14.94	0.09 decrease
4		@ 230°F.	14.90	0.13
5		@ 255°F.	14.89	0.14
6	Pressed between steel plates heated to	180°F.	15.00	0.03
7		230°F.	14.88	0.15
8		260°F.	14.90	0.13

None of these treatments gives anything approaching the effect of hot pressing. The apparently drastic process of prolonged boiling in water actually gives a slight gain (though this, as we have seen, is within the limits of experimental error). The effect of drying is also quite small. The failure to obtain any effect by pressing between hot plates is attributable to the rapid cooling of the plates. A definite finish was, however, imparted in spite of the fact that there was no appreciable loss of hygroscopic capacity, but the three experiments cannot be regarded as a fair reproduction of hot pressing. The above results will be discussed more fully in the next section after certain theoretical points have been considered.

Some further samples of the same material were treated in the manner specified in the first column of Table IX. The humidity at which the regains were measured was different from that of the previous series.

TABLE IX.

Treatment.		Equilibrium Regain.	Decrease of Regain caused by treatment.
Untreated		13.29	—
Stretched on a tube heated by	steam	12.56	0.73
	water @ 160°F.	12.66	0.63
	water @ 140°F.	12.74	0.55

These experiments are, of course, imitations of the Paramount process. It will be noticed that the reduction of regain depends upon the temperature.

With a view to finding out how the time of pressing affected the regain, a series of samples of web of about 64's quality was sent away to be pressed in the Pegg and Hoffmann presses for different times. They were tested in the humidity room on return in the usual manner along with an untreated sample. The results are shown in Table X. The shortest time in each case is the usual time for the class of material.

TABLE X.

Treatment.	Equilibrium Regain.	Decrease of Regain.
Untreated	13.60	
Pressed in Pegg Press 2 mins.	11.12	2.48
4 „	10.98	2.62
6 „	10.86	2.74
12 „	11.17	2.43
Pressed in Hoffman Press 7½ sec.	12.67	0.93
15 „	12.80	0.80
22½ „	12.32	1.28
80 „	11.69	1.91

These results confirm the previously obtained result that the effect of the Hoffman Press is less severe than that of the Pegg Press. The effect of the latter, moreover, takes place rapidly, since there is no progressive reduction of the hygroscopic capacity with prolonged pressing, such as occurs with the Hoffmann Press.

This progressive reduction in the case of the Hoffmann Press is shown in the following two series of experiments.

TABLE XI.
HOFFMAN PRESS.

Material.	Time of Treatment.	Regain.	Reduction.
Ribbed fabric from 2/18½ yarn	Untreated	12.63	—
	12 sec. (usual)	12.10	0.53
	36 „	11.60	1.03
	60 „	11.44	1.19
Ribbed fabric from 2/26's yarn	Untreated	12.42	—
	12 sec.	11.77	0.65
	36 „	11.32	1.02
	60 „	11.33	1.09

In Table XII. are given the results of experiments with two samples of woven fabric which were wrapper blown for different times. This process, of common application in the cloth trade, may require explanation here. The cloth is wrapped under tension along with a piece of Bolton sheeting on a perforated roller, to which steam may be admitted from one end. To the other end is attached a pump. Steam is blown through for the necessary time, and then cold air is drawn through the sample by the action of the pump. Usually the piece is reversed to ensure uniformity of treatment.

TABLE XII.
BLOWING.

Material.	Time of Blowing.	Regain.	Reduction.
White Worsted	untreated	18.06	—
	5 mins.	17.81	0.25
	10 „	17.00	1.06
	15 „	16.76	1.30
	30 „	16.09	1.97
Medium Woollen	untreated	17.56	—
	5 mins.	16.65	0.91
	10 „	16.70	0.86
	15 „	16.25	1.31
	30 „	16.22	1.34

It will be seen that the process of blowing with steam even when prolonged much beyond the usual time, does not give anything approaching so large an effect as ordinary hot pressing.

7. AN EXPLANATION OF THE EFFECT OF HOT PRESSING ON THE HYGROSCOPIC CAPACITY.

The investigation described in the foregoing section, though it has revealed a number of interesting facts about the effect of various treatments, has not reproduced in the laboratory an effect at all comparable with that produced in the factory by the action of the Pegg Press. There must, therefore, be some special feature about the treatment given by this machine, which is not found in other methods of treatment such as boiling in water, drying in an oven, etc.

Let us consider how the treatment the wool receives in the Pegg Press differs from such forms of treatment as heating in an oven, boiling in water, etc. In the first place we have in the plates of the Pegg Press a source of heat which is practically infinite, so that the contact of the cool material will not cause any appreciable cooling of the plates. Moreover, the two plates come very close together during the pressing. The wool will, therefore, even in the short time it is in the press, come nearly to the temperature of the plates. Moreover, there will be very little cooling due to evaporation, since the material is in a space which is almost closed—the only outlet for the steam being at the edges. This is a very different state of affairs from that prevailing during the drying of moist wool in an oven. In this latter case there will be considerable cooling due to evaporation, so that while the wool is moist the temperature will be relatively low. Only after the wool has become dry will it reach the temperature of the oven ; and when it is dry it is, of course, less liable to be injured by heat.

To investigate the nature of hot pressing we must therefore study the effect of heating moist wool in a closed or nearly closed space. Before studying the subject experimentally we will consider a few theoretical points. We know that in order to get a " finish," mechanical treatment of the wool when in a moist state is necessary. Let us consider what we mean by wool or other material being " moist." Let us compare cotton at 14% regain with wool at the same regain. Anyone who understands the subject at all would say at once that the cotton would be the moister. The scientific explanation of this is that the maintenance of a 14% regain in cotton requires a much higher atmospheric humidity than is required for wool. Actually the two humidities would be about 90% and 57%.

Now it has been shown by Schloesing and others that as the temperature is raised the atmospheric humidity necessary to maintain a given regain in wool is increased. Schloesing's results extend only from 12°C. (53.6°F.) to 35°C. (95°F.), but it is possible to form some rough idea of the effect of higher temperatures by the mathematical process of extrapolation. By this means the curves shown in Fig. 1

have been constructed. The abscissæ represent the regain of the wool, and the ordinates the atmospheric humidity necessary to maintain the regain. The different curves correspond to different temperatures. These curves illustrate in a rough way the effect of heating wool in a closed space (i.e., at a constant regain). Let us consider wool at 14% regain. The humidity of the atmosphere with which it would be in equilibrium at different temperatures is shown in Table XIII. These values have been obtained from the curves shown in Fig. 1.

TABLE XIII.

Temp. (C.)	% Humidity.	Temp. (F.)
0°	49	32°
20°	56	68°
40°	63	104°
60°	72	140°
80°	82	176°
100°	87	212°

We see that at, say, 20°C. (68°F.) the wool would be in the ordinary sense of the term " dry " ; at 100°C. (212°F.) the wool would be distinctly " moist "—as moist as wool at 20°C. (68°F.) would be if it had about 24% regain.

We have thus an explanation of why it is possible with the Pegg Press to get a finish without unduly moistening the goods to begin with. The heat of the plates diminishes the hygroscopic capacity of the wool and drives moisture into the air spaces between the fibres, so that during the time of pressing the air is at a high humidity and the wool is essentially much moister than it was when cold, though actually it has lost a small amount of moisture.

We will now consider some experiments on the effect of heating moist wool in a nearly closed space. Samples of wool were wetted between the folds of a cotton cloth for about half an hour and placed in a tube of such size that the wool nearly filled it. The tube was then corked, a small hole being left to obviate increase of pressure in the tube when heat was applied. The tube was then placed in a conditioning oven heated to temperatures in the neighbourhood of 230°F. Observations with a thermometer pushed well down into the wool showed that so long as the wool remained wet the temperature did not rise above 212°F. After a definite time the tube was removed from the oven and the wool taken out. Usually the fabric was appreciably yellowed and emitted an unpleasant smell as it came from the tube.

The effect of such treatment is shown in Table XIV.

TABLE XIV.

Treatment.	Equilibrium Regain.	Decrease of Regain.
Untreated	16.13	—
1 hr. @ 230°F. ...	15.68	0.45
2 hrs. „ ...	15.38	0.75
3 „ „ ...	15.14	0.99
1 hr. @ 180°F. ...	15.91	0.22
„ 200°F. ...	15.90	0.23
„ 260°F. ...	15.42	0.49

The results show that at last we have discovered an experimental routine which produces a marked effect on the hygroscopic capacity. The effect, though comparable with that of hot pressing, is nevertheless, even in the most extreme case, appreciably smaller. The samples were initially practically soaking wet (about 40% regain). Now goods going to the Pegg Press are usually much drier than this. It is conceivable that the magnitude of the initial regain may have some influence. To investigate this point a series of samples at known regains were prepared and heated in the tube for an hour with the oven at 230°F. The results of the series of regain measurements are shown in Table XV.

TABLE XV.
REGAIN OF UNTREATED SAMPLE = 13.29%.

Initial Regain.	Equilibrium Regain.	Decrease.
2.85	11.94	1.35
5.91	10.06	3.23
8.10	10.30	2.99
10.00	10.05	3.24
13.61	10.04	3.25
18.0	11.82	1.47
25.0	12.10	1.19
35.0	12.66	0.63
52.7 (hydro-extracted)	12.99	0.30

The results are plotted in Fig. 2. It will be seen that the effect of the treatment depends upon the initial regain. The effect is small if the wool is initially very dry and also if the wool is initially very wet. There is a certain initial regain at which the effect is greatest.

The explanation of the small effect of heating at a small initial regain is, that the presence of an appreciable amount of water is necessary for any injurious effect. It is, of course, well known that

wool is more liable to damage of all kinds when heated wet than when heated dry (e.g., the effect of sulphuric acid—see Publication No. 3).

The explanation of the small effect when the wool is initially very moist is not so obvious. The difference in the effect of the heat on moist wool and moderately moist wool cannot be great. Such differences as exist would favour a larger effect on the moister sample. It would appear that the essential difference lies in what happens on removal from the tube. Let us consider what happens when the samples are removed. Owing to the fact that they are warm, moisture will evaporate from them and they will cool rapidly. As they cool their hygroscopic capacity will increase. They will therefore become rapidly drier. By the time they have cooled down nearly to the air temperature, both samples will contain less moisture than they did initially. One containing initially a moderate regain, say 18%, will be " dry " in the ordinary sense of the term, but one containing, say 50%, will be " wet " even after it has cooled down. Now we have seen in Section 5 that the impaired hygroscopic capacity is restored by treating with cold water. This latter sample will exist for an appreciable time in a cold wet state. The injurious effect of the heating will there be to a large extent counteracted. The former sample will not have the benefit of this " cold wet " treatment and will therefore suffer the full effect of its " hot wet " treatment.

The explanation of the results given in Table XV. is therefore as follows. The experimental routine involves the possibility of two treatments—an injurious " hot wet " treatment and a curative " cold wet " treatment. Since wool becomes essentially wetter on heating in a nearly closed space it is not necessary that in order to receive the " hot wet " treatment the wool should have a particularly high regain. On the other hand, in order to receive the " cold wet " treatment, the wool must have a very high initial regain. The samples treated in a series of experiments such as the above may be divided into three lots which, of course, are not sharply differentiated: those which are so dry that they receive neither the " hot wet " nor the " cold wet " treatment; those which are so moist that they receive both treatments; and those at intermediate initial regain which are moist enough to receive the " hot wet " treatment, but not moist enough to receive the " cold wet " treatment. These latter are, of course, those whose hygroscopic capacity suffers most.

This theory explains why we do not get much injury to the hygroscopic power by boiling in water. This is, of course, a " hot wet " treatment—but it is followed by a curative " cold wet " treatment when the wool is removed from the water. Even if it is put in a hot

oven to dry immediately on removal from the hot water its temperature will fall owing to the cooling by evaporation (the " wet bulb " effect).

In Table XVI. are tabulated summarised explanations of the effect of a number of treatments. The signs + and — in the second and third columns are used to denote respectively the presence and absence of the treatment at the head of the column. Thus ordinary hot pressing consists of "hot wet" treatment not followed by " cold wet " treatment. It results, therefore, in a large effect on the hygroscopic capacity.

TABLE XVI.

Treatment.	Hot wet.	Cold wet.	Effect of treatment on hygroscopic capacity.
Drying in oven	—	—	small
Boiling in water	+	+	small
Ordinary hot-pressing	+	—	large
Heating in tube : low initial regain ...	—	—	small
" " medium initial regain	+	—	large
" " high initial regain ...	+	+	small

A large effect results from "hot wet" treatment not followed by "cold wet" treatment, while a small effect results from either both treatments or neither.

There is one crucial experiment which will test the correctness of this explanation. If we can submit the material to the "hot wet" treatment and also avoid even the slightest trace of "cold wet" treatment, we should obtain an effect larger than we have hitherto obtained. To do this we must dry the material while still hot. Now drying involves cooling due to evaporation. To avoid appreciable cooling the drying must be very slow. Some wool was heated wet in a nearly closed tube in the oven at 112°C. (228°F.) for about one hour, heated air was then aspirated slowly through the tube. The rate was so slow that a thermometer placed in the wool did not go lower than 90°C. (194°F.). When the wool was fairly dry it was taken out and its equilibrium regain tested in the usual way. It was also wetted out and tested again. The results were as follows :

Regain of comparison sample	14.14
Regain of sample after heating ...	10.60
Decrease of regain	3.54
Regain after wetting	13.24
Increase or recovery of regain	2.64

This decrease is very much greater than anything which has been previously obtained in the laboratory and is greater even than what has been obtained with certain hot-pressed samples. It cannot therefore be doubted that the above explanation is the correct one.

8. CONCLUSIONS TO BE DRAWN FROM THIS WORK.

From the purely practical standpoint the Hot Press is open to objection. It is not a continuous process and is expensive in labour. There is a feeling in the trade that the time is ripe for some better process. Bearing these practical objections in mind, the objections from the scientific point of view which have been adduced in this paper become of special interest. Although the question of weight affects directly only a section of the trade, it cannot be denied that a 2% loss must ultimately become the concern of all sections. The question of the production of a satisfactory finish without such a large loss of weight is therefore an important matter. It will be dealt with in Part III. of this work.

This work has also an important bearing on the question of standard of regain. The standard for hosiery (and other) yarns is 18¼%. Experiments conducted at Torridon show that this corresponds to a relative humidity of about 82% at ordinary temperatures. This is much higher than the average indoor humidity in England, so that from this cause alone there will be a considerable discrepancy between the weight of the yarn (in standard condition) and the weight of goods produced. Added to this there will be also the loss due to impaired hygroscopic capacity. The magnitude of this effect varies. An average case for hot-pressed goods is shown in Table XVII. and Fig. 3. The data relate to a Botany web of 60's quality.

TABLE XVII.

% Humidity.	% Regain.		
	Unfinished.	Finished.	Difference.
50	14.01	11.93	2.08
67	17.00	14.35	2.65
74	17.97	15.06	2.91
78	18.95	15.78	3.17
81	20.32	16.77	3.55

These figures show that it would be an extremely difficult matter to bring pressed goods to the 18¼ standard. The highest humidity shown in the table is higher than that given by any ordinary conditioning cellar, and it gives a deficiency of 1½% regain.

A standard for such finished hosiery goods, to be logical, would have to be about 3% lower than the yarn standard, and even then it would be high. A standard of about 12½% would be more suitable.

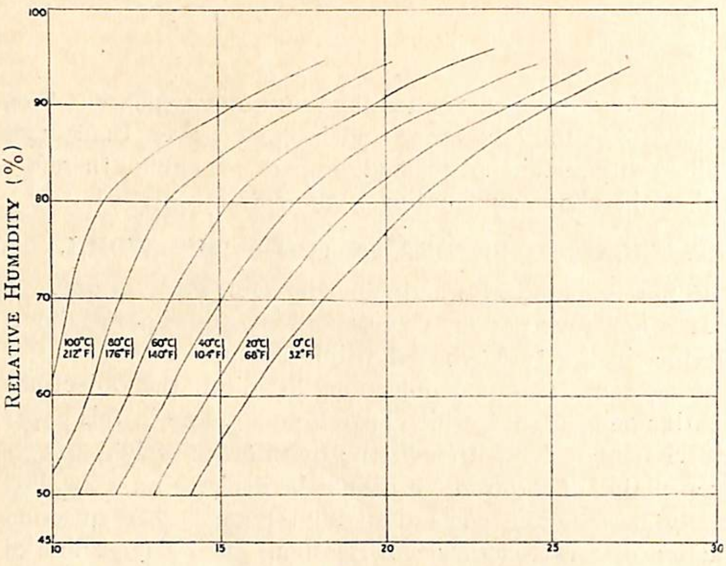

Fig. 1. Regain (%)

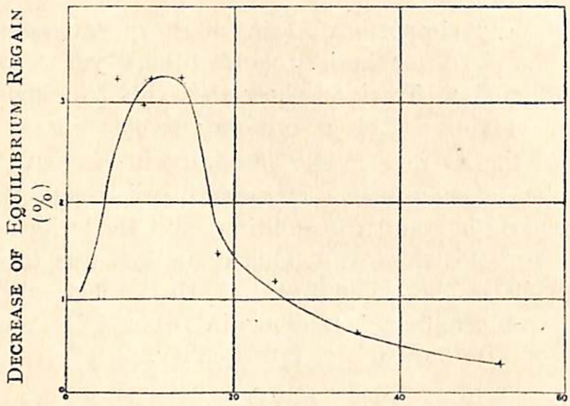

Fig. 2. Initial Regain (%)

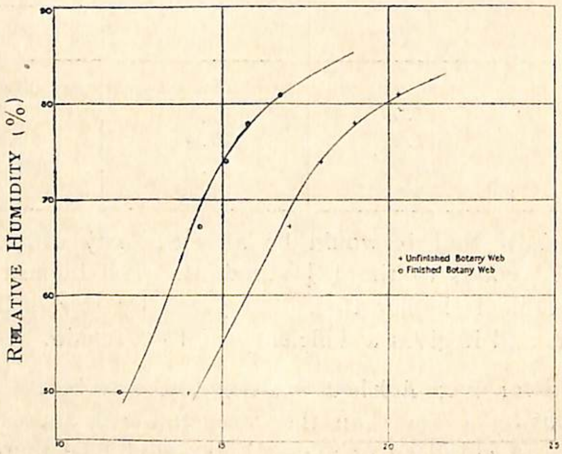

Fig. 3. Regain (%)

REGAIN.

EXPLANATORY NOTE.

Relative Humidity. This is a numerical measure of the dryness or dampness of the air. If the air is saturated and will absorb no more moisture, we say the relative humidity is 100%. If the air is absolutely devoid of moisture, we say the relative humidity is 0%. In this climate the natural relative humidity of the atmosphere may be very low (as on a bright frosty morning), or it may be nearly 100% (as in misty weather).

The degree of dryness or dampness of the atmosphere depends not merely on the amount of moisture in a given volume of air, but on the relation between this amount and the amount required to saturate the air. This latter amount varies very rapidly with the temperature. Thus at 40°F. it is 2.9 grains per cubic ft.; at 50°, 4.1; at 60°, 5.8; at 70°, 8.0; and at 80°, 11.0. Roughly speaking, a rise of temperature of 20°F. doubles the amount of moisture required to saturate the air.

It follows, therefore, that if we are merely told the amount of moisture in the air, say 4 grains per cubic foot, we have no information as to the dryness or dampness of the air. If the temperature were 50°F. the air would be nearly saturated; if 70°F., the air would be fairly dry, containing only half the amount of moisture required to saturate it; at a still higher temperature the air would be still drier.

The state of the atmosphere with respect to dryness and dampness is thus specified by the actual moisture content expressed as a fraction or a percentage of the amount required to saturate the air. Thus 4 grains per cubic ft. corresponds to 98% relative humidity at 50°F. and to 50% at 70°F. In the following table are given as an illustration of this the grains per cubic ft. corresponding to different percentage humidities at different temperatures.

Temp. °F.	Relative Humidity (Percentage). 100%	90%	80%	70%	60%	50%	40%	30%	20%	10%
40	2.86	2.57	2.09	2.00	1.72	1.43	1.14	0.86	0.57	0.29
50	4.10	3.69	3.28	2.87	2.46	2.05	1.64	1.23	0.82	0.41
60	5.77	5.19	4.62	4.04	3.46	2.89	2.31	1.73	1.15	0.58
70	8.01	7.21	6.41	5.61	4.81	4.01	3.20	2.40	1.60	0.80
80	10.98	9.88	8.78	7.69	6.59	5.49	4.39	3.29	2.20	1.10
90	14.85	13.37	11.88	10.49	8.91	7.43	5.94	4.46	2.97	1.49
100	19.84	17.86	15.87	13.89	11.90	9.92	7.94	5.95	3.97	1.98

Regain. It is common knowledge that various substances such as wool, cotton, linen, paper, leather, tobacco, wood, etc., absorb moisture to a degree depending upon the atmospheric conditions. This power of absorbing moisture seems to be due to the extremely fine sponge-like structure possessed by these bodies. Such substances are called colloids. They possess properties very different in many respects from the so-called crystalloids or bodies with a crystalline structure, e.g., soda crystals.

Now the precise estimation of the amount of water in such materials as wool (which is expensive and absorbs large quantities of moisture) is of great importance commercially. This amount is specified by means of a quantity called the "regain." The regain of a sample of wool is the amount of water it contains expressed as a percentage of the dry weight (not as a percentage of the total original weight). Thus if a 1lb. sample lost 3oz. on drying, the regain would be 3oz. expressed as a percentage not of 1lb. but of 13oz., i.e., it would be

$$\frac{3 \times 100}{13} \text{ or } 23.08\% \text{ Regain.}$$

The dry weight of 13oz. would have to regain 23.08% to get back to its original weight of 1lb., hence the term "regain."

Standard Regain. For convenience and avoidance of disputes, certain standards of regain are recognised, e.g., 18¼% for yarn. Yarn at this regain is regarded as correct, and if it has more or less moisture, an allowance is deducted from or added to the price. It is by no means certain that the Standard Regains in this country are the most suitable for the climate and for safe storage. Other countries impose other standards. This question is under investigation by the Association.

Dry Weight. The "dry weight" of a sample of wool is defined as the weight obtained by drying the sample in an oven in a current of air at a temperature of from 220° to 230°F. till no perceptible change of weight is detectable in consecutive weighings at an interval of about 8 minutes.

Equilibrium Regain. When wool in any form (top, cloth, etc.) is placed in an atmosphere of constant temperature and humidity, it will in general begin to gain or to lose moisture. This process will go on for some time but at a gradually diminishing rate till finally the wool attains a certain weight and regain. This regain is called the "equilibrium regain." The determination of this equilibrium regain for different humidities and temperatures is a matter of considerable importance.

This information, however, is necessary for the proper understanding and control of certain industrial processes. For example, in French drawing, artificial humidification is necessary for the satisfactory processing of the wool, since the regains corresponding to ordinary indoor conditions are too low. Again, such knowledge of the relation between regain and atmospheric conditions affords information as to the capabilities of a conditioning room for yarn or hosiery. The regain of wool exposed to ordinary atmospheres in this country varies over a wide range—roughly from 30% to 12%. The upper limit would correspond to a nearly saturated atmosphere—the lower to a relative humidity of about 45% (which for our climate is very low).

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